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Art. X.—*A Practical Application of Photoperiodic Response to Plant Breeding Methods at the State Research Farm, Werribee.*

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I. Introduction.

Since the discovery by Garner and Allard(2, 3, 4) of the phenomenon of photoperiodic response, the subject has been investigated and developed rapidly in many directions, until, at the present time, it has assumed a practical importance to the plant breeder. Extensive reviews of the literature on the subject have been written by Kellerman(6), Redington(8), Schick(9), and others, and obviate the necessity of any general introduction here. Numerous workers, including Oden and Rasmusson(7), Tschermak(11), Schratz(10), and Harrington(5), have recorded the production of two generations of plants in one year, by the use of artificial illumination. The purpose of this paper is to indicate the methods adopted at the Victorian State Research Farm, Werribee, to obtain three generations of wheat and barley hybrid material in twelve months. Under conditions of normal daylight prevailing in the southern States of Australia, the production of two generations of cereals in one year is possible, and is the accepted practice in South Australia at the Waite Research Institute and at Roseworthy Agricultural College, and in Victoria at the State Research Farm, Werribee. At the last-mentioned station (lat. 37° 54′ S.), the summer day exceeds fifteen hours from late November to late January, and enables material sown in early December to develop rapidly and mature fully in ample time for sowing during the normal seeding months of May and June. This treatment is normally applied to first generation material.

II. Experimental.

During 1930-31 it was decided to attempt the production of an extra generation in the period February to June, by subjecting the plants growing during this period to artificial illumination sufficient to give them the equivalent of a sixteen-hour day, a possibility suggested by the work of Forster and co-workers(1) on the photoperiodism of wheat varieties.

It was obvious that the adoption of such a course would necessitate the harvesting of the grain in an immature condition in the first and second generations, and in view of this, series of tests were made to determine the effect of such harvesting on

the germination of the grain. Samples of Pryor barley were harvested in two stages of development, air-dried for twelve days, and subjected to laboratory germination tests.

TABLE I.—BARLEY GERMINATION TEST.

Stage of Grain When Harvested.	Per Cent. Germination at—				
	48 Hours.	72 Hours.	96 Hours.	168 Hours.	216 Hours.
I. Milk stage	6·0	22·8	34·0	43·5	56·8
II. Dough stage	0·5	27·0	51·5	72·5	81·5
Number of grains per sample, 400.					

The results given in Table I. indicated that a satisfactory germination could be obtained from barley harvested in the early stages of maturity.

A test with the wheat variety, Free Gallipoli, yielded similar results, which are shown in Table II. Grain was harvested in five stages of development, air-dried for fourteen days, and germinated. A satisfactory germination was obtained only in the case of sample V. The results indicated that the early dough stage was probably the earliest at which wheat could be harvested to ensure a satisfactory germination in the following generation.

TABLE II.—WHEAT GERMINATION TEST.

Stage of Grain When Harvested.	Per Cent. Germination at—				
	72 Hours.	120 Hours.	168 Hours.	240 Hours.	336 Hours.
I. Grain half formed ..	..	..	3·0	3·1	12·5
II. Grain two-thirds formed ..	..	..	..	8·3	23·3
III. Three-quarters formed ..	1·0	1·0	5·7	15·5	30·1
IV. Fully formed, milk stage ..	1·0	3·0	14·0	33·0	51·0
V. Fully formed, dough stage	4·6	14·6	46·0	82·8	95·4
Number of grains per sample, 300–400.					

During the two years in which the experiments have been in progress, the progeny of five different barley matings were successfully carried through three generations (F1, F2, and F3 plants) in one year. In addition, three generations of the wheat variety Rajah were produced during 1930-31. The behaviour of the three barley hybrids, and the wheat variety Rajah, comprising the 1930-31 material, is summarized in Table III. In the case of the hybrids, matings were made in the field on 2nd October, 1930, and the treated ears were harvested

seven weeks later, the grain being fully developed and hard. After being air-dried for eleven days, the F1 was sown in the plant-breeding cage on 1st December. Germination was rapid, and was complete by 10th December. All plants were in ear by 16th January, 1931, the time required from germination to heading being from 35 to 39 days. The first batch of plants was harvested on 5th February, when the grain was fully formed and in the dough stage. A second batch was taken twelve days later when the grain was just colouring. Both lots of plants were air-dried, the first for fourteen days, the second for six. The grain from these was sown in the cage on 19th and 23rd February. Germination was complete by 28th February in the first case, and from this date until harvest, 89 days later, all

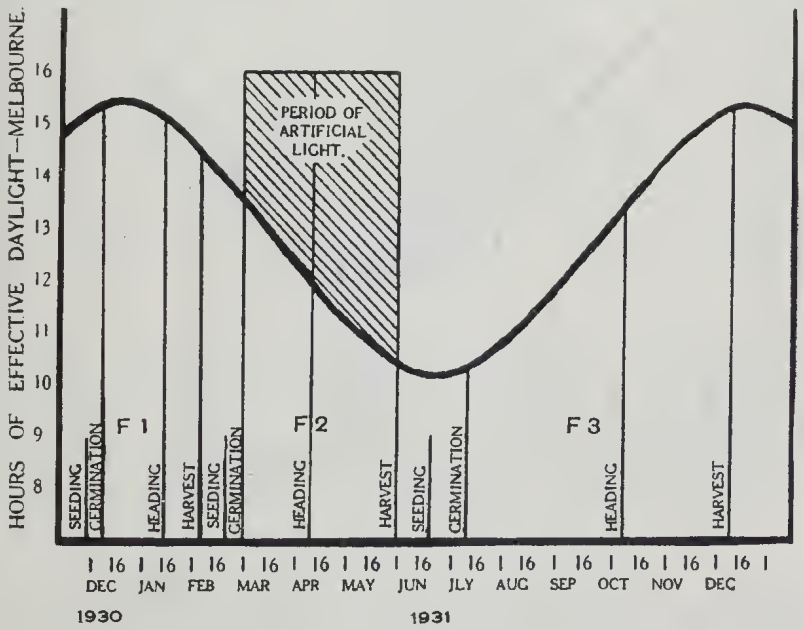

Fig. 1.—Barley Matings, 1930-31.

plants were subjected to an additional daily period of illumination to bring the total "length of day" up to sixteen hours. The lighting system was automatically controlled by means of a clock which enabled the extra illumination to be applied in the mornings. Again, the plants were harvested in an immature condition, after the grain was fully formed; they were then air-dried for sixteen to twenty-one days. The F3 families were sown in June in the field, where they developed normally and matured in December. The general behaviour of these three generations, in relation to the conditions of normal daylight prevailing at Melbourne throughout the year, is represented

graphically in Figure 1. The wheat variety Rajah behaved in a manner essentially similar to that of the barleys except that the time required for development was rather longer.

The 1931-32 material consisted of the progeny of two barley matings. These were effected in the field on 27th Octoer, 1931, harvested 34 days later in the late dough stage, and sown in the cage on 1st December. As was the case of the 1930-31 material, the F2 was the only generation to receive artificial light. Oven-drying of the seed was substituted for air-drying in this generation, and resulted in a saving of several days between F2

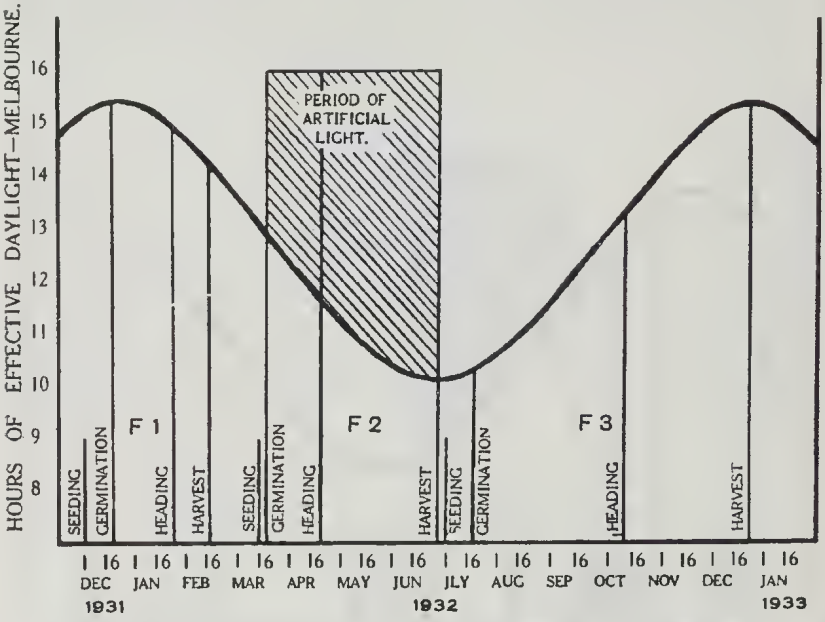

FIG. 2.—Barley Matings, 1931-32.

and F3. The behaviour of this material (Table IV.), was essentially similar to that of the previous season, and three generations were again obtained in the year. The results are represented graphically in Figure 2.

III. Discussion.

The outstanding feature of the experiment was the marked response of the F2 plants to long day conditions. In all cases the time required from germination to heading, by plants in this generation, was approximately the same as in the F1 grown under the normal summer day of fifteen hours. On the other hand, F3 plants in the field receiving an average of only twelve hours daylight, required from two to three times the number of days to develop. It is thus obvious that length of day is a major factor influencing time of flowering in the varieties under

consideration. In its relation to the maturity of the grain, however, photoperiodism is of definitely lesser importance, and is superseded by temperature as a major factor. The results have indicated striking differences in the time required by the plant to mature its grain, the most rapid development occurring in the case of the F1 grown during the summer months when the temperature is high. In the case of the F2, which develops a few months later when the average daily temperature is decreasing, it is doubtful whether complete maturity could be accomplished. At this time the grain develops rapidly until it is fully formed, but the final stages of drying out and hardening, accompanied by the change in colour, are definitely retarded. For this reason harvesting in an immature condition must be resorted to.

One of the most striking features of the experiment was furnished by the barley hybrid material, the F2 plants of which exhibited marked degrees of individual response to long day conditions. These responses were most marked in the case of the 1931-32 hybrids, probably on account of the great differences in the length of growing period characteristic of the parent forms under normal conditions. In one culture of 30 plants, 22 responded to long day conditions, suggesting a single-factor difference for this character.

Other points of interest were the production of twin grains and of branching stems by some of the plants grown under the intensive conditions. Neither of these characters was inherited.

The necessity of harvesting the plants in an immature condition, and the fact that the scope of the work is limited by the area under controlled lighting, furnish the two most serious drawbacks to the scheme, which is however of definite value in special cases.

It is essential that this method of accelerating breeding operations be confined to the early generations, since it will be realized that the selection of desired types is impossible under the artificial environment induced by controlled lighting. By growing the F1 in summer, subjecting the F2 to controlled lighting, and selecting in F3 under field conditions, it is possible to produce homozygous F4 selections for sowing the following year, thus effecting a saving of two years in the breeding programme.

In conclusion, the writer wishes to record his indebtedness to Mr. H. A. Mullett, Director of Agriculture, Department of Agriculture, Victoria, under whose supervision the work was conducted, and to Professor S. M. Wadham, School of Agriculture, University of Melbourne, for his helpful criticism and suggestions.

TABLE III.—BARLEY AND WHEAT, THREE GENERATIONS, 1930-31.

Illumination.	F.1. Normal Day = 15 Hours.				F.2. Normal Day, + Light = 16 Hours.				F.3. Normal Day = 12 Hours.			
Mating.	Date of—				Date of—				Date of—			
	Seeding.	Germination.	Heading.	Harvest.	Seeding.	Germination.	Heading.	Harvest.	Seeding.	Germination.	Heading.	Harvest.
Barley—												
Pryor × Himalaya	1.xii.30	8.xii.	16.i.31	5.ii. 17.ii.	19.ii. 23.ii.	28.ii. 10.iii.	8.iv. 15.iv.	28.v. 2.vi.	18.vi.	9.vii.	12.x. 14.x.	12.xii.31
Pryor × Skinless	1.xii.30	9.xii.	14.i.31	5.ii. 17.ii.	19.ii. 23.ii.	28.ii. 10.iii.	6.iv. 13.iv.	28.v. 2.vi.	18.vi.	9.vii.	9.x.	12.xii.31
Pryor × Balkuling	1.xii.30	10.xii.	14.i.31	5.ii. 17.ii.	19.ii. 23.ii.	28.ii. 10.iii.	8.iv. 15.iv.	28.v. 2.vi.	18.vi.	9.vii.	12.x.	12.xii.31
Wheat—												
Rajah	1.xii.30	10.xii.	27.i.31	17.ii.	23.ii.	9.iii.	27.iv.	13.vi.	4.vii.	24.vii.	2.xi.	30.xii.31

TABLE IV.—BARLEY, THREE GENERATIONS, 1931-32.

Illumination.	F.1. Normal Day = 15 Hours.				F.2. Normal Day, + Light = 16 Hours.				F.3. Normal Day = 12 Hours.			
Mating.	Date of—				Date of—				Date of—			
	Seeding.	Germination.	Heading.	Harvest.	Seeding.	Germination.	Heading.	Harvest.	Seeding.	Germination.	Heading.	Harvest.
Pryor × Pusa 20 ..	1.xii.31	18.xii.	28.i.32	13.ii.	8.iii.	15.iii.	18.iv. 21.iv.	24.vi. 24.vi.	28.vi. 28.vi.	15.vii. 15.vii.	11.x. 15.x. 19.x. 11.x. 15.x.	21.xii.32
Pusa 12 × Plumage Archer	1.xii.31	18.xii.	23.i.32	13.ii.	8.iii.	15.iii.	16.iv.	24.vi.	28.vi.	15.vii.	11.x. 19.x. 22.x.	21.xii.32

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